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ARE CURRENTLY AVAILABLE FLAMMABILITY AND FLAME-RETARDANT TESTS APPLICABLE TO UPHOLSTERED FURNITURE AND MATTRESSES?[1]

by

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The hazards associated with the ready combustibility of textile products and wood have been of serious concern to man ever since he learned to use fire for constructive purposes.

Sabattini as early as 1638 published studies on flammability and resistance of textiles to burning. The use of cellulosic fibers in clothing and household fabrics increased manyfold over the next 300 years. Concurrently the need to give cellulosic fibers and textile products an ability to resist burning was increasingly recognized. This was mainly because wool, silk, and some other natural fibers exhibited more inherent flame resistance than did cellulosic fibers (6).[3]

For this publication, cushioning materials for mattresses and furniture are included in the definition of textile products.

The terms generally used in defining the combustibility of textile products are sometimes misleading and confusing (12).

"Fire resistance" and "flame resistance" are frequently used in the same context as the terms "fireproof" and "flameproof." Textile products that are flame resistant or fire resistant will not continue to burn or glow once the source of ignition has been removed. Fire or flame will produce some change in their physical and chemical characteristics. Fireproof or flameproof, on the other hand, refer to materials that are totally resistant to fire or flame. They demonstrate no physical or chemical changes.

Glow resistance in many textile products is of equal importance to flame resistance. Most fibrous organic fillers used in cushioning applications continue to undergo a slow oxidative decomposition even after active flaming has subsided. This afterglow is as hazardous or more so than open flame because its temperature often reaches 300°F. above that of the flame temperature. Afterglow is usually accompanied by the generation of dense and sometimes toxic gases (6).

Natural fibers (such as cotton, flax, silk, and wool), manmade fibers (such as rayon, nylon, polyesters, vinyls, and acrylics), inorganic

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2/ One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, U.S. Department of Agriculture.

3/ Underscored numbers in parenthesis refer to Literature Cited at the end of the publication.

fibers (such as glass and asbestos), and synthetic or natural foams such as polyurethane, vinyl chloride and natural rubber) each have their own characteristic ease of resistance to ignition and combustion.

Many factors affect the flame resistance of textile products. Some of these factors are the type of fibers used, the inherent ease of ignition of the fibers, the melting or non-melting characteristics of the fibers, the physical state or geometry of the fibers in the finished product, the synergistic effect of two dissimiliar materials in contact or close proximity to each other, and the presence or absence of flame-retardance treatments.

The spatial orientation of a textile product directly affects its ability to resist flaming or burning and also frequently affects the type and course of the combustion that ensues. For example when a cigarette, an electrical short circuit, a match or other source of thermal energy ignites a textile product containing cotton batting, a smoldering or glow type of combustion usually results if the product is in a horizontal position. However, if the cotton textile product is in a vertical position or any position other than horizontal active flaming frequently occurs (14).

The contact or close proximity of dissimiliar materials often changes the course of combustion, and usually worsens the problem of flame retardance[4/]. For example, polyester fibers are more difficult to ignite than cotton or rayon. They give off more thermal energy during burning than does cotton. With the polyesters, some melting takes place during burning. In some situations this results in self extinguishing characteristics that can be attributed to the physical removal of the melt by dripping (10). When polyester fibers are blended with cellulosic fibers, the matrix inhibits or slows down the removal of the melt and the products are quite flammable[4/]. Similarly, polyurethane foam tends to melt or shrink away from a heat source, particularly where the source does not include an open flame. If, however, the foam is covered by a ticking or upholstery fabric sufficient thermal buildup can occur and the product will ignite and burn fiercely.

For mattresses the problem is further complicated by the presence of sheets, blankets, quilts, and bedspreads each of which often contains a variety of fibers of differing degrees of flame retardance. Each of these fabrics can, and frequently does, contribute to the fires that account for about 1,700 deaths that occur in the United States each year (1, 10, 13).

Many of the deaths resulting from bedding fires are caused by asphyxiation rather than from burns (7).

Such fires tend to smolder and burn slowly over a long period of time and generate copious quantities of noxious smoke and toxic gasses (14), meanwhile depleting the available oxygen.

Cellulose, nylon, polyesters, natural latex, and polyurethane foam have no appreciable vapor pressure at normal room temperatures and, therefore, do not burn per se. When these materials are subjected to high temperature they decompose into compounds that are flammable. The combustion of these flammable components of

4/ Tesoro, Guiliana C. and Meiser, Charles H. Jr., Some Effects of Chemical Composition on the Flammability Behavior of Textiles. Presented at the 39th Annual Meeting of the Textile Research Institute, Apr. 9-11, 1969, New York, N.Y.

decomposition generates more heat which causes further degradation and decomposition. This cycle continues until complete disintegration and oxidation of the material has taken place (6).

Decomposition takes place in two stages. First there is the heterogeneous generation of gaseous, liquid, tarry, and solid byproducts. The second stage is the slow oxidation of the residue from the first stage. The latter continues until the carbonaceous char is consumed. Effective flame retardants characteristically reduce the ignition point and the temperature of combustion for cotton products. Presumably this would be true also for synthetic fibers and polyurethane foam. By lowering the effective temperatures of ignition and combustion and by interfering with the decomposition cycle so as to reduce the amount of flammable byproducts, flame retardancy is achieved. Ideally, a flame retardant for most organic materials should direct the decomposition so that only carbon and water are formed as end products (6).

The oxidation of carbon can take place through either of the reactions shown below:

(1) $C + 1/2\ O_2 \rightarrow CO \quad \Delta H = -26.4 KCal.$

(2) $C + O_2 \rightarrow CO_2 \quad \Delta H = -94.4 KCal.$

To suppress afterglow, the course of the combustion must be directed to favor the first equation because the oxidation of carbon to carbon monoxide does not generate sufficient thermal energy to sustain the afterglow of the char.

Test Methods

Any consideration of the measurement of flammability of flame retardance of assembled items of home furnishings, such as mattress and upholstered furniture, discloses the fact that two distinct aspects coexist. From the consumer viewpoint the interest is in the performance of the finished product, which includes many components. On the other hand, the manufacturer must concern himself with the performance of the individual components as they affect the ultimate performance of his finished product.

There is a wide diversity of opinion as to what should be measured to permit the categorization of textile products for their flammability or flame retardance (11). Thirty-six or more test methods for measuring flame resistance have been accepted or suggested by various technical societies and governmental agencies (11). Some of the most widely used tests are listed below:

- Vertical
- Inclined (45°)
- Horizontal
- Differential Thermal Analysis
- Thermogravimetric Analysis
- Ignited Cigarette
- Hot Rivet
- Methenamine Tablet
- Limiting Oxygen Index
- Optical Smoke Density

The results obtained with the different tests are significantly at variance, which suggests that each test procedure is measuring something different from the others.

Among the burning characteristics that are not adequately covered by existing test methods are such important properties as:

- Ease of ignition
- Ease of extinction
- Smoldering combustion
- Flame intensity
- Flame propagation
- Self extinguishing characteristics
- Byproducts of combustion
- Afterglow

There are two general classes of flame-retardance tests that have received wide acceptance: (1) The fire resistance tests for measuring the resistance of products to ignition, flaming, and glowing.

(2) The flammability tests for measuring the rate of burning and the relative inflammability and self-extinguishing characteristics (6).

There are other considerations as well. The burning rates of many textile products are extremely sensitive to the handling and preparation that occurs before the sample is placed in any test apparatus (6). For example, a normal operating procedure at the Southern Regional Research Laboratory, samples of cotton batting, are maintained under four environmental conditions before testing for flame retardance. These conditions are 70°F. and 65 percent relative humidity for 24 hours, 100° and 100 percent R.H. for 3 days, 158° for 16 hours, and soaking with water and drying for 16 hours at 158°. All of these conditions conceivably could be encountered in normal use of mattresses and upholstered furniture, and each exerts a characteristic effect upon the flammability data that are obtained by any of the test procedures that will hereafter be discussed.

Probably the best known and used fire resistance test is the vertical flame test. This test is usually considered one of the most difficult to pass. At the left of figure 1 is a typical arrangement for the test. The sample on the left has not been treated for flame retardance. The other sample has been treated.

Figure 1

The lower edge of the 12-1/2 x 2 inch sample suspended vertically hangs 3/4 inch into a 1-1/2 inch high yellow luminous flame from a Bunsen or Tirell burner (4). After 12 seconds the flame is removed. The duration of afterflame and afterglow, main and overall char are measured with the difference between the latter two values giving an indication of the propensity of the sample to flash. To the right in figure 1 is shown typical sample appearance after testing. Note that the treated sample resisted burning and was self-extinguishing, while the untreated sample was almost completely consumed.

Figure 2 shows some additional typical results obtained with a series of flame-retardant treated

Figure 2

cotton batting and a control after testing by the vertical method. While the rating of the samples is not absolute in terms of numerical values, it is obvious from figure 2 that differences in performance can be observed. Compare for example the char lengths for samples A and C with those of Samples B and the control.

If a sample passes the vertical flame test, no significant performance data can be obtained by use of the flammability test procedures. Flammability tests are primarily designed to rate samples that burn faster than can be measured with the vertical test.

There are similarities in the construction of mattresses and upholstered furniture, and there are important differences also. Both mattresses and upholstered furniture (figure 3) essentially consist of a

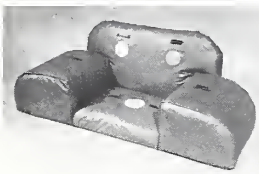


Figure 3

filling material covered by a suitable fabric. The covering fabrics for these products are usually made from fibers that differ chemically from the filling material. In normal use, approximately 25 percent of the exposed surface area of a mattress is in the vertical position. For upholstered furniture, the vertically positioned materials frequently exceed 60 percent of the exposed area. Construction of a mattress is such that a certain integrity exists which makes the interior of the product rather inaccessible to ignition from external sources. In contrast, upholstered furniture ordinarily consists of separate cushions which to varying degrees broach the interior integrity of the product. A source of ignition could conceivably penetrate the voids between cushions and, under the proper conditions, sponsor ignition which to all intents behaves as if the fire were initiated in the interior of the product. There are serious doubts, therefore that mattress manufacturers would be willing to accept the premise that their products should be evaluated for flame retardance by the same test procedure as would be used on upholstered furniture.

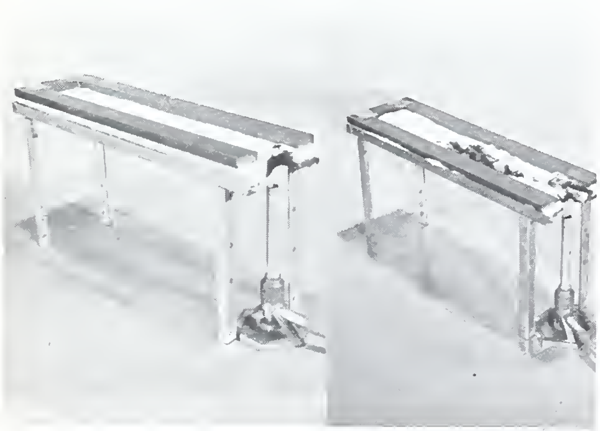
It is important, however, to recognize that the manufacturer of polyurethane foam, textiles, or cotton batting has no direct control over the position or orientation of his product in the finished mattress or item of furniture. As a consequence all cushioning products should pass the most demanding of test procedures to insure adequate performance regardless of spatial orientation in ultimate use is achieved.

Because of the differences that might be introduced by an assembly, a manufacturer must not only test components but also mock-up products. Such tests are necessary even though the individual components themselves are adequately flame retardant.

A number of tests can be used to determine a relative degree of flammability. In general, these are used to evaluate materials that would fail to pass a vertical test. They are designed to differentiate between rates of flame or glow propagation as a function of the position of the sample during test. Both inclined (45° angle) and horizontal positions are used. In the inclined test (2) a sample 6 inches by 2 inches is subjected to a flame from a microjet for 1 second. If the sample is ignited, the time of flame travel over 5 inches is measured and used as an indication of the relative flammability of the material. The problem here is that the time of exposure to the flame is frequently insufficient to

ignite the material if it demonstrates only a minimum of flame retardancy. Even so, this test procedure is often found to be too stringent for some highly flammable textile products, and in such cases a horizontal test is used (2, 6).

One horizontal test (3) uses a sample 4 inches by 14 inches not over 1/2 inch thick. A Bunsen or Tirell burner having a flame height of 1-1/2 inches is directed against the edge of the sample for 15 seconds. Afterflame and smoldering are reported in addition to the rate at which the sample burns between marks spaced 1-1/2 inches and 11-1/2 inches from the ignition point. Results typical of this test procedure are shown in Figure 4. The



A B
Figure 4

left hand sample is untreated cotton batting, while that on the right has been treated for flame retardance.

Other test methods that are closely related to the horizontal test are the methenamine-timed burning tablets and real or simulated cigarettes, book matches, or wooden matches. Where the methenamine tablet is used it is placed in the center of a sample, and carefully ignited by touching a match to its edge, while avoiding contact of the match with the sample surface. The tablet is allowed to burn itself out, and any ignited or propagated flame is

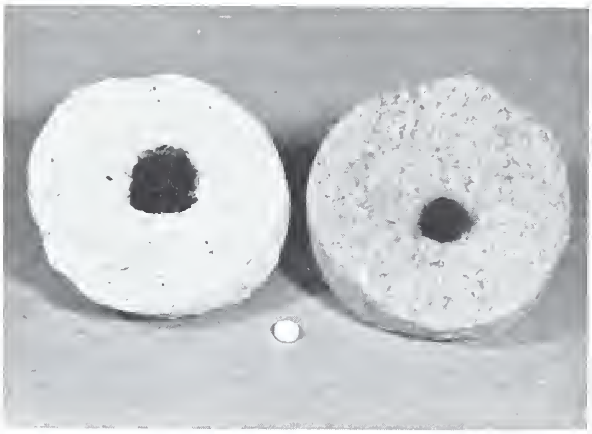


Figure 5

permitted to burn to completion. The maximum diameter of the charred area is measured to the nearest tenth of an inch. See Figure 5.

This test method is not very sensitive as can be seen from figure. Not only is it impossible to measure the effect of flame-retardant concentration, it is quite difficult to note differences in afterflame and afterglow for a variety of flame retardants applied at various levels. In this illustration the sample on the right had been treated, the other had not. The problem of interpretation may be due to the low temperature of the fabric-tablet interface, which is between 390° and 490° F., and that the char formed provides sufficient insulation to inhibit further degradation. The hottest part of the methenamine tablet flame is about 670° and this is directed away from the sample surface. In many tests the area of the sample immediately under the tablet does not show scorching until the tablet is completely consumed. The use of cigarettes has also been suggested as a test procedure (5). Their use, however, introduces a multitude of other variables that are difficult to control. The temperature of the glowing tip of

a cigarette is not a constant. It depends upon how dry or how damp the tobacco is, how tightly or loosely the tobacco is compacted, and whether or not the cigarette is actively being smoked or passively laying on a surface. These variables significantly affect the temperature of the glowing tip, with differences in temperature as great as 500° F. for certain combinations. In addition the ash from cigarettes can and does catalyze certain pyrolysis reactions. Different brands of cigarettes yield ash of significantly different chemical content. At the other extreme is the tendency of moisture from the combustion of the tobacco to condense on the surface of the cigarette in contact with the sample. This results in a low temperature at the interface which is often below that needed to ignite the sample. Therefore, for a cigarette to ignite textile products certain very specific conditions and spatial arrangements must exist that are conductive to ignition.

Research data are available to show that the total energy incident on a surface or edge is more important than the temperature of ignition in predicting the flammability of a textile product. The type of energy--conductive, convective, or radiant--also plays a large part in the response of the product. As a consequence, these factors are critical in assessing the hazard, and in the design of laboratory tests 5/. Paper book matches, small wooden matches, large kitchen matches, cigarettes, and similar manufactured products are variable and of uncertain value in test procedures that seek reproducibility.

The validity of using certain tests to evaluate the flammability or flame retardance of mattresses or upholstered furniture regardless of the materials of construction is questionable. A case in point is the use of a hot rivet or bolt to establish the relative flammability or flame retardance of such products. Cotton batting and polyurethane foam have widely divergent physical form. They can, therefore, be expected to behave in entirely different ways when they are exposed to thermal stress from a hot rivet.

Polyurethane foam, being a thermoplastic, inherently tends to shrink away from a source of heat. In the process it loses its identity as a foam and becomes a liquid. A hot rivet applied to an exposed slab of foam can be expected to melt through the material. The melting of polyurethane is endothermic which results in rapid absorption of the heat from the rivet. In contrast, cotton batting does not melt or shrink away from a source of thermal energy. It retains its identity as a fiber until consumed by burning. Because it retains its physical form, cotton batting tends to retain a hot rivet in contact with its surface for a longer period of time than would foam, and thus it is exposed to greater thermal stress. Both cotton batting and polyurethane foam will ignite if sufficient thermal energy is provided to exceed their critical ignition temperatures. Cotton batting products tend to smolder for long periods, bursting into open flame no matter what the source of ignition, only under certain very specific conditions. Once ignited by a flame, polyurethane foam melts and burns furiously and is quite difficult to quench. Covering cotton batting or polyurethane foam products with fabrics compounds the problem, and makes the

5/ Seaman, R. E., Laboratory Evaluations to Predict Fabric Flammability. Presented at the 39th Annual Meeting of the Textile Research Institute April 9-11, 1969, New York, N.Y.

prediction of flame retardance or flammability even more difficult.

The use of a hot rivet or bolt to measure the flammability or flame retardance of mattresses and upholstered furniture is unrealistic and unreliable because it fails to provide for inherent differences in the physical characteristics of the materials being evaluated.

Differential thermal analysis, thermogravimetric analysis and limiting oxygen index are concepts of the measurement of pyrolysis reactions sometimes invoked in the assessment of flame retardance and flammability.

Differential thermal analysis (DTA) involves a measurement of the temperatures in a reference material and a sample as they are both heated at a uniform rate (9). The continuous comparison of the temperatures permits the recording of deviation and indicates whether the change is endothermic or exothermic. Thermal changes can be measured in air, nitrogen, oxygen, or mixtures of gasses.

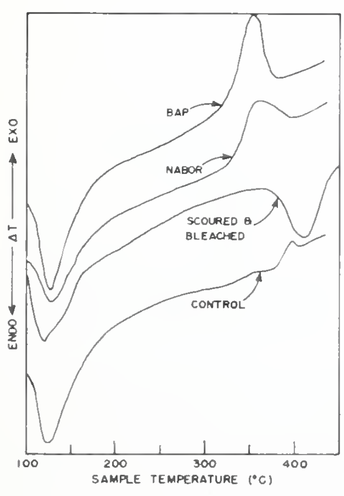


Figure 6

Figure 6 shows a typical DTA for cotton batting. The bottom curve is for untreated native linters and textile wastes as used in conventional cotton batting. The first deflection in all of the curves indicates a loss of moisture. Note that the control has a small exotherm at 395°C. The next curve up shows the DTA for scoured and bleached cotton batting. This material has a large endotherm at about 405°C whereas the control had an exotherm 10° lower. The top two curves show the changes in pyrolysis pattern resulting from the treatment of the cotton batting with sodium borate and with borated amido polyphosphate. Each of these treated samples shows a large exotherm. For the sodium borate the peak is at 350° and for the borated amido polyphosphate it is at about 345°.

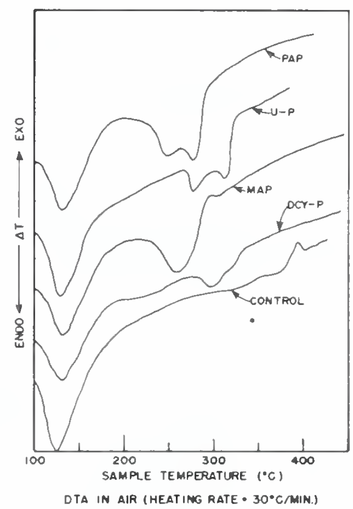


Figure 7

The choice of the flame retardant has a significant affect upon the shape of the differential thermal analytical curve (figure 7). The endotherm for the loss of water slightly above 100°C. is again present in all cases. Starting at the top of figure 7 with the propyl ammonium phosphate curve, note that there are two endotherms with the major deflection at 275°. The next curve below shows urea phosphate treated cotton batting. It too has two deflections with the major low point at 275° and a secondary low point about 40° higher. The next

curve is for monoammonium phosphate treated batting. It shows a major endotherm at about 255°. The next curve shows a small endotherm for dicyandiamide-phosphoric acid treated cotton batting. In this case the endotherm is at 290°. These exotherms and endotherms reflect the chemical changes that occur as thermal energy is supplied to the sample.

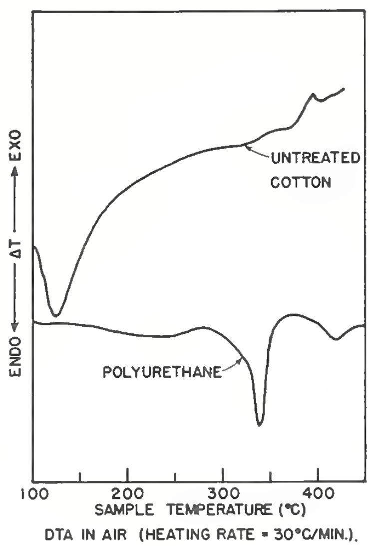


Figure 8

Figure 8 shows a typical differential thermal analysis of polyurethane foam. The initial minima at slightly above 100°C that was present for all of the cotton samples is missing for the foam. The first point of interest is the large endotherm at 337° which is probably associated with melting and decomposition.

It is extremely important to be aware that the data derived from differential thermal analysis will vary with the rate of temperature rise during heating, consequently DTA cannot be used to predict the flammability or ignition point of materials. Test results obtained when samples are heated at the value of 30°/min. would not be comparable with the results that would be obtained if the samples were heated at 3° per minute. However under specific conditions for a number of samples, data obtained can be compared to show differences in behavior. If thermogravimetric (TGA) tests are run under conditions that match those of the differential thermal analysis, then more reliance can be placed on the data derived (9). Thermogravimetric analysis consists of measurement of the changes in weight that accompany thermal stress applied at a preselected rate. By comparing the curves for DTA and TGA, changes in weight corresponding to endothermic or exothermic change can be established.

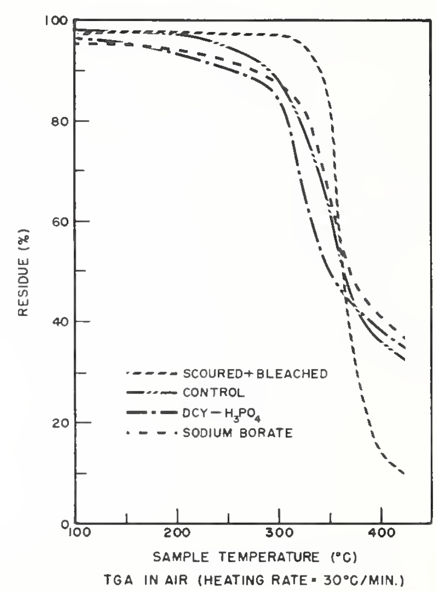


Figure 9

Figure 9 shows a significant difference in residue obtained by TGA procedures for scoured and bleached fibers and for a control batting containing native unscoured and unbleached linters and textile wastes. At 425°C. the control sample had a residue of 32 percent while the scoured and bleached fibers had only 10 percent. This difference was suggested by the differential thermal analysis results shown in Figure 7. Note also that the temperature of onset of thermal degradation or decomposition of the

control was almost 100° lower than was obtained for the scoured and bleached fibers. Sodium borate and dicyandiamide-phosphoric acid treated samples have slightly more residue than the control. Both of these samples begin to decompose at approximately the same temperature. For the treated samples the temperature of onset of decomposition is approximately 30° lower than for the control, and 130° lower than for scoured and bleached fibers.

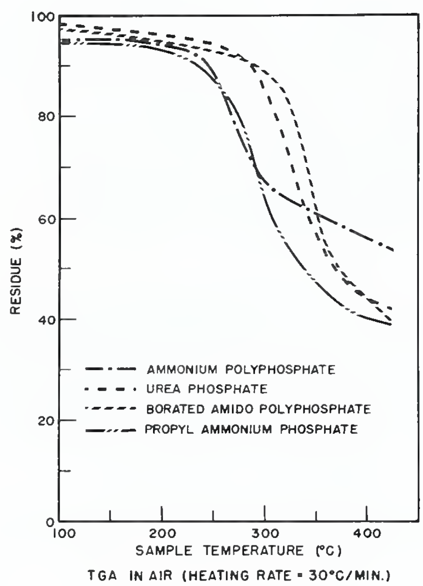


Figure 10

The selection of the flame retardant plays a large part in determining the temperature of decomposition. It influences the amount of char or residue that remains after pyrolysis. Figure 10 shows that the onset of decomposition for this group of samples was 320°C. for the borated amido polyphosphate treated sample, 258° for the propyl ammonium phosphate, 293° for the urea phosphate, and 245° for the monoammonium phosphate. The residue after pyrolysis was about 39 percent for both the propyl ammonium phosphate and the borated amido polyphosphate, 42 percent for the urea phosphate, and 55 percent for the monoammonium phosphate. The values for the onset of decomposition in both the DTA and TGA agree quite well with significant changes evident in the DTA and TGA curves at corresponding values. Comparison between samples undergoing DTA and TGA analysis are valid only when the specific conditions under which the samples are tested are identical. It is important to recognize that thermograms from both DTA and TGA techniques show net change only. Two or more competing or reinforcing reactions may occur simultaneously, in which case only the net difference will appear in the thermogram. Pyrolysis is a very complex reaction with many chemical changes taking place concurrently. With DTA and TGA techniques, it is not possible to separate the individual endothermic and exothermic reactions that occur simultaneously. It is only possible to record the sum of the effects.

Another test procedure that offers some promise as a tool for the rating of samples of textile products is the limiting oxygen index [6]. The method involves the measurement of the minimal volume fraction of oxygen in a slowly rising gaseous atmosphere that is capable of sustaining a small candlelike burning of the sample. It affords a convenient and reproducible indication of the flammability of the material being tested. For most materials the results obtained are independent of the physical form and dimensions of the sample within rather broad limits. The technique seems to be particularly valuable in measuring the effect of chemical composition on flammability. In general, untreated cotton textile products have limiting oxygen index values that fall between 0.190 and 0.210.

6/ See footnote 4.

This minimal volume fraction of oxygen in the combustion atmosphere is fairly close to the normal oxygen content in air. In contrast, flame-retardant treated cotton products have limiting oxygen index values of 0.230 to 0.250, or values for oxygen content that are significantly higher than that of normal air. Polyester fibers have limiting oxygen index values of about 0.205. These values are quite close to those obtained for cotton. Limiting oxygen index values of 0.250 to 0.280 have been obtained for vinyl chloride.

The limiting oxygen index can be used to differentiate between samples that are readily flammable under normal oxygen content in air and for products that require a considerably higher volume percent of oxygen to burn. Again a word of caution is needed. Under the conditions of the test some samples that showed values of 0.230 limiting oxygen index could easily be ignited and would burn in air under certain conditions.

Apart from fatalities caused by direct ignition of bedding and furniture, smoke and toxic combustion products may be regarded as a major cause of deaths in fires. To draw a distinction between the hazards of smoke inhalation and toxic combustion gas inhalation is difficult (11) since these occur simultaneously with oxygen depletion. There is general agreement that the smoke hazard precedes that of toxic gasses. One method of estimating the smoke concentration is by the use of optical density techniques, in which optical density is defined as the negative logarithm (base 10) of the fraction of light transmitted across a selected length of the smoke path. The optical density is directly proportional to the nature and concentration of the smoke. Cellulose fibers give comparatively low smoke factors but high optical densities, whereas fibers that melt give high smoke factors and lower optical densities. In other words, materials that char produce finer smoke particles which give a high degree of light scatter, whereas materials that melt upon exposure to flame produce coarse smoke particles (8). Large smoke particles are particularly undesirable since they may function as a nucleus for condensation of fire fighting foam or toxic chemicals.

From the consumer standpoint, the performance of the article of trade that he purchases is the ultimate criterion for judgment. This, of course, raises many questions and problems in the establishment of test procedures to evaluate certain physical or chemical characteristics.

Some of the differences between mattresses and upholstered furniture that need to be considered, if these articles are to be tested with the ultimate consumer in mind, are given below:

Bare mattress vs. made up bed
(Inherent differences in components)

Mattresses vs. upholstered furniture
(Differences in construction)

Variables in use vs. realistic test conditions

Mattresses, insofar as the consumer is concerned, are rarely used as they come from the manufacturer. They are covered by such items as sheets, blankets, and spreads; consequently, when they are subjected to sources of external heat the mattresses are in a sense isolated from that thermal energy by at least one thickness of fabric. The manufacturers of mattresses can argue with some logic that this situation offers them some leeway in the degree or amount of flame retardancy that their

products really need in practice. But, is this really true? Composites of different fibers and fabrics are known not to behave as would be predicted from their individual characteristics insofar as flammability is concerned. As a consequence the presence of a sheet over a mattress could actually increase the potential flammability of the assembly and could contribute to the propagation of the burning once the assembly is ignited. Any test method that would be developed to evaluate a mattress for flame retardance or flammability that included the use of sheets, blankets, quilts, and spreads would be suspect because these products are made from many different fibers and are of different constructions. The variables introduced would, therefore, outweigh the possibility of obtaining objective test results.

Another big question in the evaluation of the flame retardance of completed mattresses is the adequacy of treatments that are applied only to the ticking. Here again, there are pros and cons. Two points of interest are: (1) Is it possible to treat mattress ticking in such a manner that it will have sufficient tear or bursting strength after charring to maintain the integrity of the interior of the mattress? (2) Can flame-retardance treatments confer insulative properties to the charred material which would assure that the filling material would never receive sufficient thermal energy to reach its critical ignition temperature?

Experience to date indicates that unequivocable yes answers to these questions cannot be given. Consequently dependence upon the ticking or upholstery fabric to provide adequate flame retardance to an assembled item could be hazardous and unreliable.

Much of what has been said for mattresses also applies to upholstered furniture. However, in upholstered furniture the predominance of vertical surfaces in many sofas, chairs, multi-purpose furniture and other specialty items introduces different problems. It is, therefore, doubtful that a test method devised for mattresses could be used with impunity for upholstered furniture. In sofas and upholstered items, the presence of removable cushions and entries into the interior of the article presents other complications that would be distinctly different from what is encountered in mattresses.

Mattresses and upholstered furniture are used under a wide range of environmental conditions. What then constitutes a reasonable set of conditions on which flame retardance and flammability can be based?

Textile products that successfully pass even the vertical flame test at 65 percent relative humidity often fail when tested after conditioning at 10 percent relative humidity. Similarly samples that are tested in a draft-free chamber and that pass the vertical flame test do not necessarily pass the test when a draft is induced. What then would constitute a valid basis for testing, a draft-free chamber to simulate a room with closed windows, or a room in which the windows are open to a breeze? It should be emphasized that data obtained from any flame retardance or flammability test rates the performance of the materials only under the specific conditions of the test being used. Comparisons are valid only when made from data from a particular test run under precisely controlled conditions. Projection of performance under one set of conditions to an entirely different set of conditions is not reliable; in fact, it is highly speculative.

Obviously, there are many more variables that enter into the evaluation of finished mattresses and upholstered furniture than have been suggested in this publication. The concept of testing finished articles of furniture and mattresses presumes that sufficient data are available to establish realistic standards of performance for each different item under the conditions selected for evaluating their performance. From a scientific and objective viewpoint this is not the case for furniture or mattresses.

SUMMARY

Some of the parameters involved in the evaluation of mattresses and upholstered furniture for flame retardance and flammability have been explored. A brief description of the mechanism of combustion has been given.

A number of the most widely used test methods for the evaluation of the components that go into mattresses and furniture for their flame resistance and their flammability have been discussed, and some of their advantages and shortcomings noted.

Some basic considerations that need to be taken into account to develop acceptable test procedures for fabricated mattresses and upholstered furniture have been outlined.

From the discussions in this article, it can be concluded that sufficient data are not now available on which realistic standards of performance can be established. Available test methods cannot predict the performance of products under all conceivable conditions.

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